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Acid Rain

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ACID RAIN

ISSUE DEFINITION

Acidic precipitation, or acid rain as it is commonly called, has become a subject of major concern to many Canadians. When the acidification of lakes was first described in Ontario in the early 1950s, the phenomenon was considered to be simply a local problem resulting from the lakes' proximity to nickel smelting operations in and around Sudbury. Since then, however, scientists have documented the acidification and the demise of numerous additional lakes; acidification is now acknowledged to be widespread and a major environmental problem.

Acidic precipitation is derived principally from emissions of sulphur and nitrogen oxides which are released to the environment during the combustion of fossil fuels and the smelting of sulphide ores. As the pollutants are transported for hundreds, or perhaps thousands, of kilometres through the atmosphere, the oxides enter into a complex series of chemical reactions to form acids. Sulphuric and nitric acids are the most frequently found types.

Freshwater ecosystems are most vulnerable to the harmful effects of acidic precipitation but damage can be inflicted on man-made structures and artifacts as well. The effects of acidic precipitation on terrestrial ecosystems, including agricultural crops and forests, are not well-defined although most authorities agree that a potential for damage exists. Recently, scientists have become concerned about the relationship between acid deposition, in combination with other air pollutants, and forest damage in Europe and Eastern North America.

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BACKGROUND AND ANALYSIS

Acid rain is not a new phenomenon. In the mid-seventeenth century, Evelyn (in 1661) and Gaunt (in 1662) noted the influence of industrial emissions on the health of plants and people and the transboundary exchange of pollutants between England and France. They suggested remedial measures including the placement of industry outside of towns and the use of taller chimneys to spread the "smoke" into "distant parts". In 1872, Smith, in a pioneering publication entitled "Air and Rain: The Beginnings of a Chemical Climatology", first used the term "acid rain" and described many of the concepts we now consider part of the acidic precipitation problem. More recently, Scandinavian countries have been severely polluted by acid rain and much research has been carried out in these countries to study the impact of acidic precipitation on forest and freshwater ecosystems.

In 1978, in response to mutual interests and concerns, the Governments of the United States and Canada established a United States-Canada Research Consultation Group to study the problem of the long-range transport of air pollutants (LRTAP). This Group was to study LRTAP and the related phenomenon of acidic precipitation and to aid in the coordination of research studies and the exchange of scientific information between the two countries. A preliminary report released by Environment Canada in October 1979 "identified acidic precipitation as the problem of greatest common concern at the present time."* On 5 August 1980, Canada and the United States signed a "Memorandum of Intent Concerning Transboundary Air Pollution" as a preliminary step in the development of a bilateral agreement on air quality which would deal effectively with such pollution and, at the same time, combat acidic precipitation. However, no substantial agreement has yet been reached on this issue.

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* A.P. Altshuller and G.A. McBean, U.S. Co-chairman and Canadian Co-chairman of the United States-Canada Research Consultation Group on the Long-Range Transport of Air Pollutants (LRTAP), "The LRTAP Problem in North America: a preliminary overview", October 1979, p. 24.

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A. Acidity

Acidity is a measure of the concentration of hydrogen ions (H^+) in solution; as the concentration of hydrogen ions increases, the solution becomes more acidic and, conversely, as the concentration of hydrogen ions decreases, the solution becomes less acidic (or more alkaline). Acids are compounds which release hydrogen ions upon dissociation; thus, when they are added to water they make it acidic.

The concentration of hydrogen ions in solution can be measured quantitatively and is expressed as a "pH value". The pH scale ranges from 1 to 14, with 7 being the halfway point between a very acidic solution of pH 1 and a very basic, or alkaline, solution of pH 14. The pH number is the negative logarithm of the hydrogen ion concentration; thus, lower numbers represent greater hydrogen ion concentrations. At pH 7, acidity and alkalinity balance each other and such a solution is described as neutral. Finally, it should be noted that, because the pH scale is a logarithmic scale, a solution with a pH of 4.6 is ten times as acidic as a solution with a pH of 5.6; a solution with a pH of 3.6 is one hundred times as acidic as a solution with a pH of 5.6.

B. Formation of Acid Rain

Pure water is a neutral compound and thus has a pH of 7, but even natural unpolluted rain is not pure water; it is a dilute solution of carbonic acid which forms from the atmosphere's natural content of carbon dioxide. This acid dissociates in water to release only enough H^+ ions to lower the pH of precipitation from 7 to about 5.6; thus, the acidic precipitation which arises from man's pollution of the atmosphere has a pH below 5.6.

Acid rain is formed when pollutant compounds, primarily the oxides of sulphur and nitrogen, react with oxygen and moisture in complex reactions in the atmosphere to form acids. Although the details of the chemical reactions which take place in the atmosphere are not completely understood, some of the oxides of sulphur and nitrogen are converted to sulphuric and nitric acids, respectively. These are strong acids and they dissociate completely in water releasing hydrogen ions to solution; thus,

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they can lower the pH of precipitation significantly. One of the most acidic rainfalls yet recorded fell in Scotland in 1974 and was measured at 2.4 on the pH scale -- roughly the pH of vinegar (dilute acetic acid) and over one thousand times as acidic as natural rain. In December 1982, a sample of fog taken at Corona del Mar in Southern California had a pH of 1.69. This extremely high acidity developed after a two-day ground-level temperature inversion in the Los Angeles basin which prevented air pollution from dispersing.

C. Emissions of Acidifying Pollutants in North America

The most important acidifying air pollutants are sulphur dioxide (SO_2) and nitrogen oxides (NO_x). The most comprehensive information on emissions of SO_2 and NO_x now available is for the base year 1980, although there is also some information on emissions in more recent years.

In 1980, Canadian emissions of SO_2 totalled some 4.6 million metric tons (tonnes), with slightly less than 50% coming from the non-ferrous smelting sector. Emissions of SO_2 in the United States amounted to 24 million tonnes; thermal power generation contributed about two-thirds of this total. On a per-capita basis, then, Canada produces about twice as much SO_2 as does the United States. SO_2 emissions in both countries have a strong regional character: about 80% of total emissions come from provinces east of the Manitoba-Saskatchewan border and from the 31 states east of the Mississippi River in the U.S.A.

Emissions of NO_x in 1980 are estimated to have been 21 and 1.7 million tonnes in the United States and Canada, respectively. In both countries, the transportation sector and electric power generation are the largest contributors, the latter being particularly significant in the U.S.A. Emissions of NO_x are more uniformly distributed than those of SO_2, but more than 60% of emissions are contributed by the eastern regions. On a per-capita basis, the United States produces more NO_x than does Canada.

The emissions inventories for SO_2 and NO_x in North America are not precise, but the errors are estimated to be less than 10% on a national basis. The seasonal variation in emissions is fairly small and is

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estimated to be less than ± 10% from the national average. In some areas of Canada, however, the phenomenon of "acid shock" is important in the spring of the year. This occurs when acidifying pollutants, particularly NO_x, accumulate in the snow pack and are released in a short period of time during snow-melt.

The acid-forming potential of SO_2 emissions in eastern North America is approximately twice that of NO_x emissions. Natural (versus anthropogenic) emissions of SO_2 and NO_x probably contribute to the acid rain phenomenon, but this contribution is small in eastern North America compared to the quantities of anthropogenic emissions.

Over the past 30 years, there has been considerable fluctuation in SO_2 and NO_x emissions in North America. Emissions of SO_2 peaked in the late 1960s and early 1970s in both countries and have dropped since. Recent estimates indicate an accelerated decline in SO_2 emissions from 1979 to 1982, partly due to the economic downturn. There may have been a slight increase in 1983, coincident with the economic recovery. NO_x emissions in Canada and the U.S.A. have increased greatly since the 1950s, from 9 to 21 million tonnes in the U.S.A. and from 0.6 to 1.7 million tonnes in Canada.

The characteristics of emission sources have also changed. Most noteworthy has been the progressive increase in the proportion of SO_2 released from tall stacks and this has enhanced the potential for long-range transport of this pollutant.

Deposition patterns and loadings (the amount of pollutant deposited on a unit area) are important considerations in the acid rain scenario. During the preparation, several years ago, of the Memorandum of Intent Work Group Reports, the target loading of 20 kilograms per hectare per year (20 kg/ha/yr) of wet sulphate in precipitation was proposed as a level that would provide protection for the aquatic environment, except for the most acid-sensitive lakes and rivers. These most sensitive aquatic ecosystems may not be protected if total (wet plus dry) sulphate deposition exceeds 12 kg/ha/yr.

In recent years, southern and central Ontario and Quebec have had a wet sulphate loading in excess of 20 kg/ha/yr, as has most of the United States east of the Mississippi Valley. In Canada's Atlantic

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Provinces, the wet deposition rate is close to the 20 kg mark and is slightly exceeded in some places in some years. In western Canada, loading appears to be below 20 kg/ha/yr and the same is true for the United States.

D. The Growth of the Acid Rain Problem

Acid rain is not a new phenomenon although public perception of the problem is a recent development. Scientists have now managed to accumulate adequate data from an expanded system of monitoring stations to define the geographical extent and severity of this problem. Acid rain is not often an obviously damaging pollutant; with the exception of "acid shock" caused by snow-melt, the ecological consequences of acidic deposition become apparent only after an extended period of time, perhaps decades. This fact explains much of the current anxiety over the potential ecological and economic impacts of acidic precipitation. Many environmental scientists believe that by the time damage becomes obvious, too much acid will have accumulated for ameliorative action to be taken at reasonable economic cost, and that the environmental damage may be essentially irreversible.

One of the main reasons for the increase in the extent and severity of acidic precipitation has been the construction of "super stacks" at utilities and smelting facilities. These stacks were originally built, sometimes by government order, to improve the ambient air quality in the immediate vicinity of power plants and smelters. It was generally believed that building tall stacks would bring about mixing of the flue gases with large volumes of air which would dilute the pollutants to essentially harmless concentrations. Unfortunately, while ambient air quality improved greatly, the pollutants ultimately were spread over a much larger geographic area and, moreover, the greatly increased transport time permitted the sulphur and nitrogen oxides to react in the atmosphere to form acids and acid precursors. The longer that SO_2 remains airborne, the greater the amount that is converted to sulphate or sulphuric acid.

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E. Environmental Effects of Acid Rain

More is known about the effects of acid rain on some sectors of the environment than on others. A good deal is known about the effects of acidification on aquatic ecosystems but much less is known about the effects on terrestrial ecosystems or on agricultural crops.

1. Aquatic Ecosystems

Aquatic organisms vary greatly in their ability to tolerate fluctuations in the acidity of their environment. Some species are very sensitive to acidification and, as the pH of lakes, rivers and groundwaters decreases, the least-tolerant species disappear first, followed by less sensitive species as the pH continues to drop. In southern Norway and Sweden, for example, the acidification of lakes has resulted in the decline of various species of fish, with trout and salmon being amongst the first to disappear. In Ontario, a well-documented sequence of decline follows the order: lake trout, brook trout and walleye, with perch being one of the more resistant species.

With reference to specific effects of pH, mortality of lake trout and brook trout alevins incubated in containers of gravel (pH 5.5) was significantly higher than of those incubated in limestone materials (pH greater than 6.0). Similarly, mortality of Atlantic salmon fry in limestone-treated water (pH 6.1) was significantly lower than mortality of fry in untreated water (pH 5.0). Moreover, studies have shown that the number and diversity of fish species decrease in lakes when the pH drops below 6.0.

Organisms other than fish are affected by acidification. Algal communities become less diverse in lakes as the pH drops below 6.0. The survival of rooted plants is generally diminished in acidified lakes and, conversely, the growth of benthic (bottom-growing) mosses and attached algae is usually enhanced. As the pH falls, the number of invertebrates in the water column and in the sediments decreases, the rate of decomposition of organic matter decreases, and fungi begin to replace bacteria as the dominant decomposer organisms. These developments can lead to a reduction

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in nutrient cycling in a lake, and this in turn can result in reduced productivity.

The loss of species from an ecosystem reduces the diversity of that ecosystem and may make the whole community progressively more unstable. Thus, even if a species happens to be acid-resistant, it may nevertheless be doomed to extinction if its natural prey is acid-sensitive and disappears from the environment.

In some cases, acid conditions may not kill adult organisms directly but their reproduction may be affected. Furthermore, some organisms may be acid-resistant but sensitive to metal pollution. Metallic ions are generally more soluble under acidic conditions; consequently, elevated levels of metals may themselves harm some organisms, or they may act synergistically with acid conditions to bring about physiological stress and the eventual demise of susceptible species. Elevated concentrations of aluminum, manganese, zinc, cadmium, lead, mercury, copper and nickel have frequently been observed in acidified lakes although it is not yet known whether these metals originate from deposition with the acid rain or whether they are leached from sediments by the acidified waters.

Surveys have indicated that approximately 14,000 Canadian lakes are currently acidified. Computer models predict that a further 10,000 to 40,000 lakes will be acidified in eastern Canada if wet sulphate deposition in the most heavily impacted regions is not decreased.

There is presently a paucity of direct evidence of changes in aquatic ecosystems in the sensitive areas of Canada as a result of acid deposition. However, loss of Atlantic salmon populations in several rivers in southwestern Nova Scotia has been recorded and fish population losses and declines have been recorded in lakes in Ontario. Moreover, extensive fish surveys in eastern Canada have confirmed that species diversity and richness are reduced in acidified surface waters.

There is now limited information that aquatic biological communities can recover fairly quickly from acidification (in years rather than decades) once the level of acid loading is reduced. The artificial "liming" of acidified waters has had some success in decreasing acidification and re-establishing some fish populations. However, the procedure is

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expensive and there are problems with it because liming is not an exact reversal of the acidification process.

2. Terrestrial Ecosystems

At the present time, there is incomplete understanding of how acidic precipitation affects terrestrial ecosystems. Terrestrial ecosystems are inherently extremely complex; so many factors influence the growth and development of land-based ecosystems that it is difficult to isolate and characterize the effects of acid rain alone. Some facts are known, however. Acid rain can: damage foliage; accelerate the erosion of the waxy covering of leaves which may lead to the loss of water or which may reduce a plant's ability to resist the attack of disease-causing organisms; inhibit the germination of seeds and the growth of seedlings; decrease the respiration of organisms living in the soil which may in turn affect the availability of some nutrients; increase the leaching of nutrient ions from the soil; and enhance the solubilization of aluminum in the soil, which can have negative effects on biological processes. On the other hand, it is not known to what extent the ill-effects listed above might be counterbalanced by the nutrient input which could be derived from the sulphur and (especially) the nitrogen compounds which are found in acidic precipitation.

There has been a marked decline in recent years in sugar maple stands in Quebec and Ontario; the affected areas are those with high loadings of atmospheric pollutants. This decline is incompletely understood but is believed to be due to environmental stresses, and acid rain has been implicated as a factor in certain locations.

The evidence to date suggests that forest decline in several parts of the world is due, at least in part, to air pollution, including acid rain. Direct association is not possible because so many factors impact on forest ecosystems, including insects, disease, adverse weather and climate, in addition to air pollutants.

Acidic precipitation has not yet been shown to damage agricultural crops directly, but air pollution in general does inhibit the growth of some commercial species. There are two possible mechanisms by which the damage from acid rain might occur; it could damage the surface of

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the plants directly or it could affect the growth of crops by altering the chemistry of the soil. Repeated rainfalls with pH less than 3 would be required to produce overt crop damage of economic significance. An important aspect of this problem concerns the deleterious effects of ozone on plants. Ozone is a major component of photochemical smog of which nitrogen dioxide is a precursor. Thus, a reduction in NO_x emissions could have the two-fold beneficial effect of reducing both acid rain and ozone pollution.

3. Human Health

Although direct effects of acid rain on human health have yet to be unambiguously demonstrated, some health authorities feel it may be injurious to some people. The possibility that sulphate air pollution might affect human health is widely accepted by medical authorities.

Extremely small particulates, formed in the atmosphere by the oxidation of sulphur dioxide, are capable of penetrating deeply into the human respiratory system. Acidic particulates can cause chronic bronchitis or emphysema, with the resultant difficulty in breathing leading to increased strain and, possibly, eventually to heart disease. Oxides of nitrogen can suppress the action of pulmonary scavenger cells whose function it is to purify the lungs by removing insoluble particulates. This effect could also lead to increased susceptibility to respiratory ailments.

A study in 1983, using eight years of data, showed an association between increased hospital admissions for respiratory illnesses in southwestern Ontario and increased ambient levels of sulphate, ozone, and temperature. It is assumed also that less severe respiratory illnesses also increased in number, but those were not recorded.

Another study compared the chronic health effects of exposure to air pollution in school children residing in Tillsonburg, Ontario (a high LRTAP community) and Portage La Prairie, Manitoba (a low-pollution community). The children in Tillsonburg had a small (2%) but statistically significant decrement in lung function and had a higher incidence of a number of respiratory symptoms. These findings are regarded as suggestive of the harmful effects of air pollutants, but not conclusive,

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and additional studies are underway to clarify the cause-and-effect relationship.

There is also a growing concern, for the first time, of acidification and possible contamination of groundwater.

Acidic water passing through plumbing may increase copper and lead concentrations in the water, and some natural spring waters from watersheds which have experienced acidification have shown elevated levels of lead, copper, aluminum, mercury and cadmium. All these metals are potentially toxic but the extent of the effects and the health costs associated with them have not yet been calculated. Asbestos contamination of drinking water is of some concern in areas where acidified water is collected in cisterns using asbestos-cement roofing tiles as catchments.

Concern has been expressed for rural subpopulations whose drinking water may be affected by acid rain. Research is needed to identify those potentially affected groups and to determine the levels of contaminants in drinking water.

4. Man-Made Structures

Acidic precipitation can contribute to the processes of materials erosion. Thus, buildings, roads, paint, sculptures and other man-made structures can be aesthetically and functionally damaged. The dollar costs of these damages to the urban environment are difficult to calculate, however. In 1985, the value of Canadian construction was $61 billion; $11 billion of this total was for repairs and maintenance. The question is, what portion of the observed corrosion and deterioration is due to the effect of acid rain? At the present time, no useful estimate can be made. The most that can be said, in advance of the extensive research needed in this area, is that air pollution has an effect on materials deterioration and acid deposition is one component of that complex situation.

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F. Areas of Canada Susceptible to Acidic Precipitation

In general, acid rain does not cause significant damage to an ecosystem unless it lowers the pH of that ecosystem. Areas of the country which have a high buffering capacity should not be seriously affected by acidic precipitation because they have the ability to neutralize the acid.

Buffering capacity refers to the ability of a solution to neutralize hydrogen ions with basic or alkaline ions so that the result is one of no net change in pH. Thus, an environment which has a large buffering capacity can neutralize acid rain, rendering it incapable of harming ecosystems. Buffering capacity is related to the amount of calcareous materials (such as limestone) in soils and rocks and dissolved bicarbonate in water. In parts of the country in which non-calcareous rock formations predominate, the environment has little buffering capacity and can consequently neutralize only limited amounts of acidic precipitation. For example, some lakes in the Haliburton-Muskoka region have lost 40 to 75% of their buffering capacity in less than a decade. Once the buffering capacity has been eliminated, acidic precipitation can no longer be neutralized, the pH of the system drops rapidly, and the ecological effects noted earlier begin to appear.

A large portion of eastern Canada particularly is based on granitic and silicious bedrock. This rock is non-calcareous and extensive glaciation has removed most of the younger calcareous deposits which may have been present prior to the Ice Ages. This has left vast areas impoverished in terms of calcareous deposits, although glacial deposits of calcareous material have produced some areas of overburden which do augment considerably localized buffering capacities. Large areas of Nova Scotia and New Brunswick, almost all of Newfoundland, most of Quebec and large areas of Ontario will be particularly susceptible to the deleterious effects of acid rain. Parts of the Northwest Territories, Manitoba and southern British Columbia are also suspected to be susceptible to acidification.

Areas of Canada which may suffer the most damage are probably located in Ontario, Quebec and Labrador because the prevailing

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wind regime over most of eastern North America is one of westerly winds. This pattern varies to some extent with season and, in the Great Lakes region, there are often air flows to the south in the winter and to the north in the summer.

PARLIAMENTARY ACTION

A. Sub-committee on Acid Rain

The House of Commons Standing Committee on Fisheries and Forestry established a Subcommittee on Acid Rain by Order of Reference of Wednesday, 30 April 1980 to enquire into the costs and effectiveness of finding solutions to the acid rain problem. The Report of the Sub-committee, STILL WATERS, was made public on 8 October 1981 and among other things recommended that the Clean Air Act be amended to enable the Federal Government to develop National Emission Standards to cover sources of sulphur dioxide and nitrogen oxides resulting in interprovincial air pollution and acid rain.

The Sub-committee was reappointed in March 1983 following receipt of an Order-of-Reference by the Standing Committee on 9 March 1983. The Sub-committee's final report on acid rain, TIME LOST, was released on 7 June 1984 and contained 16 recommendations. With the tabling of this report, the Sub-committee was dissolved under the terms of its Order-of-Reference of 9 March 1983.

On 4 June 1985, a Special Committee on Acid Rain was appointed by the House of Commons to "hold hearings to review all aspects of acid rain". The Committee is chaired by Stan Darling, M.P. and has 7 members, consisting of 5 Progressive Conservatives, 1 Liberal and 1 NDP.

On 13 February 1986, the Special Committee on Acid Rain tabled its First Report in the House. The Committee stated that it "views the Report (of the Special Envoys on Acid Rain) as having failed to adequately address critical elements in the control of acid rain", principally because the Report asks for more research and does not set targets and dates for emission reductions.

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On 29 September 1988, the Committee tabled a report that summarizes the activities of the Special Committee on Acid Rain since 1986, discusses the major issues that arose during hearings, and provides an overview of the Canadian position and progress on acid rain.

B. Clean Air Act

On 16 December 1980, the House of Commons passed Bill C-51, An Act to Amend the Clean Air Act. The amendment empowers the Minister of Environment Canada to recommend appropriate emission standards to control air pollutants from Canada which "may reasonably be expected to constitute a significant danger to the health, safety or welfare of persons in a country other than Canada." This amendment harmonizes Canada's Clean Air Act with the comparable U.S. law which has a similar provision with regard to transboundary air pollution.

CHRONOLOGY

1950s - The acidification of lakes was described in Canada for the first time in the Killarney area near Sudbury in Ontario.

1976 - The Canadian Network for Sampling Precipitation (CANSAP) began monitoring rainfall in 1976.

9-11 July 1979 - The Great Lakes Science Advisory Board warned that aquatic and terrestrial ecosystems in the Great Lakes Basin are being threatened by acid rain.

15 October 1979 - The Governments of Canada and the United States jointly released the first report of the United States-Canada Research Consultation Group (RCG) on the Long-Range Transport of Air Pollutants (LRTAP). The report recognized acidic precipitation as a problem of greatest common concern at the present time.

13 November 1979 - Canada, the United States, and the other 32 member nations of the Economic Commission for Europe signed the international "Convention on Long-Range Transboundary Air Pollution (LRTAP)". The signatories agreed to exchange data on sulphur dioxide emissions

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and on long-range industrial policies likely to affect these emissions. The Convention lacks an enforcement mechanism and does not compel the signatories to effect abatement procedures.

5 August 1980 - Canada and the United States signed a Memorandum of Intent Concerning Transboundary Air Pollution as a preliminary step in the development of a bilateral cooperative agreement on air quality which would deal effectively with transboundary air pollution.

15 June 1982 - Acid rain negotiations under the Memorandum of Intent collapsed.

February 1983 - The final reports of the Canada-United States Work Groups established in August 1980 under the Memorandum of Intent were released. The Canadian team maintained its position that the acceptable level of sulphate (from sulphur dioxide pollution) is 20 kilograms per hectare per year, and can only be achieved by halving current emission levels.

June 1983 - A series of reports on acid rain from groups in the United States was issued and, in the main, confirmed the principal points raised earlier by the Canadian government with respect to the threat posed by acidic deposition and the link to industrial SO_2 emissions. The U.S. groups included the National Academy of Sciences and the President's Office of Science and Technology Policy.

5 February 1985 - The federal government and the seven provinces east of Saskatchewan agreed to reduce annual emissions of SO_2 by 1.89 million tonnes (from a total of 4.5 million tonnes), a 42% reduction, by 1994. The financing of the reduction remained to be worked out and specific regulations have yet to be drafted by the governments involved.

6 March 1985 - The federal government stated it would contribute up to $150 million over 10 years to help modernize the smelting industry to reduce SO_2 emissions. An Environment Canada official estimated that the smelting industry could need up to $750 million in capital improvements to reduce SO_2 emissions sufficiently to meet the government's stated goals for 1994.

July 1985 - Representatives from 21 countries signed a protocol in Helsinki calling for a 30% reduction in emissions or transboundary movement of sulphur dioxide by 1993 from 1980 levels. The protocol is an instrument of the

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U.N. Economic Commission for Europe (ECE) Convention on long-range transboundary air pollution. Among the parties to the agreement are Canada, West Germany and Sweden. The United States and the United Kingdom declined to sign the protocol.

17 December 1985 - The Ontario Government announced an $85 million acid rain program, named "Countdown Acid Rain", to cut SO_2 emissions in the province by 1994 to 665,000 tonnes from the 1980 level of 1,993,000 tonnes, a reduction of 67%. Major reductions will be effected at Inco's Sudbury smelter, the Falconbridge smelter near Sudbury, Algoma Steel's iron ore plant at Wawa, and at Ontario Hydro's coal-fired power stations.

9 January 1986 - United States and Canadian envoys, Drew Lewis and William Davis, appointed in March 1985, released their report on acid rain. The report does not recommend a cleanup program; instead, it recommends an expenditure of $5 billion (U.S.) over five years to research more efficient technologies by which U.S. power plants burn coal, a major source of Canada's acid rain. Critics of the report stated that suitable technologies already exist and that the funds should be directed towards controls.

14 March 1986 - The National Research Council of the U.S. National Academy of Sciences released a study by U.S. and Canadian scientists which concluded that there is a causal relationship in eastern North America between SO_2 emissions and the wet deposition of sulphate and the progressive acidification of lakes and streams.

19 March 1986 - President Reagan gave his full endorsement to the Report of the Special Envoys on Acid Rain at the conclusion of his summit meeting in Washington with Prime Minister Mulroney.

26 March 1986 - Transport Canada published in the Canada Gazette Part II (Vol. 120, No. 8) an amendment to the Motor Vehicle Safety Regulations respecting emission standards for light- and heavy-duty motor vehicles, including automobiles, light-duty trucks, and heavy-duty vehicles. More stringent emission standards for cars and light-duty trucks will become effective on 1 September 1987, for the 1988 model year. They set lower limits for NO_x, hydrocarbons and carbon monoxide. Environment Canada estimates that the new standards will bring about a 45% reduction in automobile pollution by the year 2000.

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September 1986 - The United States Court of Appeals overturned an earlier lower court (26 July 1985) ruling that would have compelled seven states (including Kentucky, Ohio and Illinois) to reduce emissions blamed for causing acid rain in Canada. The appeal was made by the U.S. E.P.A. on 24 September 1985. The original suit was pressed by New York, seven other states and other interested groups and individuals.

23 February 1987 - The Government of Ontario filed a petition with the U.S. Supreme Court in Washington to appeal an earlier lower court decision allowing mid-western U.S. utilities to continue emitting high levels of sulphur dioxide. The Ontario action parallels that of eight eastern U.S. states, including New York and Massachusetts.

10 March 1987 - Environment Minister Thomas McMillan signed an agreement with Ontario on acid rain control, formalizing a February 1985 agreement to reduce eastern Canada's sulphur dioxide emissions by 50% by 1994. Prince Edward Island and Newfoundland signed similar agreements on 9 March 1987. Negotiations were continuing with New Brunswick and Nova Scotia.

20 March 1987 - The federal and Quebec Governments signed an acid rain control agreement. Noranda Inc. will reduce sulphur dioxide emissions from its Horne Smelter in Rouyn-Noranda by 50% when a new sulphuric acid plant comes into operation in 1989. The company will be assisted by more than $83 million in loans from the two governments.

6 April 1987 - Prime Minister Mulroney and President Reagan held their third summit meeting in Ottawa. President Reagan agreed that acid rain is a problem and said he would consider a Canada-U.S. accord on the issue, but did not suggest when the U.S. would act to reduce sulphur dioxide emissions which cause acid rain in Canada.

10 April 1987 - Environment Minister Thomas McMillan and Manitoba's Environment Minister, Gerard Lecuyer, signed an agreement to reduce the province's SO_2 emissions by 25% by 1994 compared to allowable 1980 levels. The agreement included an offer by the federal government to contribute $20 million to the Hudson Bay Mining and Smelting Company smelter at Flin Flon to help achieve emission reductions.

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May 1987 - Ontario Environment Minister James Bradley announced in the legislature that the emissions banking provision for Ontario Hydro would be deleted from provincial regulations. The announcement followed a unanimous recommendation from the legislature's Select Committee on the Environment on 11 May.

17 September 1987 - The United States National Acid Precipitation Assessment Program (NAPAP) presented its interim report. The report's Executive Summary tended to downplay the seriousness of acid raid in the United States and the E.P.A. has said that the evidence presented in the report indicates that increased acid rain controls are not necessary at the present time. The Minister of Environment Canada described the NAPAP report as "flawed, incomplete and misleading" and "out of step with prevailing scientific judgment and expert opinion". Other critics, in the the U.S.A. and Canada, have said the report's Executive Summary is a politically-biased document that does not fairly represent the scientific facts. A senior U.S. State Department official said that the NAPAP report supports Administration policies on acid rain.

8 October 1987 - The New Brunswick government signed a written agreement with the federal government to reduce SO_2 emissions in 1994 by 16%, from 1980 allowable levels. The agreement was signed by Premier Richard Hatfield, who was defeated in a general election five days later. The province still has to bring in the necessary emission-control regulations.

November 1987 - After a meeting in Geneva of the United Nations Economic Commission for Europe (ECE), held to discuss a draft protocol for NO_x emissions, Canadian negotiators received negative publicity in the media for an apparent refusal to support an across-the-board 30% reduction. In fact, these discussions are at an early stage and Canada proposes to link nitrogen deposition to environmental consequences. Also, the deposition of nitrogen compounds in many areas in Europe is six to ten times what it is in Canada and, therefore, a percentage reduction in NO_x emissions appropriate for Europe is not necessarily appropriate for Canada.

30 November 1987 - In a formal meeting between Canadian and U.S. negotiators, to discuss reductions in acid-rain precursor emissions, the Americans were unable to respond to a Canadian proposal for reduction of U.S. SO_2 emissions by 50%, pending a meeting of the U.S. Domestic Policy Council. The DPC met in early January and the Canadian and U.S. negotiators will meet formally in Washington on 25 January 1988.

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December 1987 - The U.S. Senate Committee on Environment and Public Works approved a comprehensive set of Clean Air Act amendments. The amendments include a three-stage phased reduction in SO_2 emissions, totalling 12 million tons by the year 2000: by 1993, the reduction would be 5 million tons, with an additional 5 million tons by 1998 and a final 2 million tons by 2000. The amendments reportedly will face opposition in the House and the Senate.

6 January 1988 - The Minister of Environment Canada, Thomas McMillan, released a critique of the NAPAP Interim Assessment: The Causes and Effects of Acidic Deposition. The Minister also wrote to the EPA Administrator, Lee Thomas, enclosing a copy of the critique. Mr. McMillan's letter, and the critique, were both very critical of the Executive Summary of the NAPAP Report.

25 January 1988 - A meeting between Canadian and U.S. officials failed to achieve any agreement on reduction of U.S. emissions of sulphur dioxide. Canada has been seeking a commitment from the U.S. to reduce SO_2 emissions by 50% by 1994, based on 1980 levels. There seems to be little or no likelihood that any agreement will be reached during the tenure of the Reagan Administration.

12 February 1988 - The federal and Nova Scotia governments signed an agreement respecting an acid rain reduction program. The purpose of the agreement is to reduce wet sulphate deposition in Eastern Canada in accordance with the Federal/Provincial Environment Ministers' Agreement of 5 February 1985. In a parallel action, taken to assist the provincial government financially, the federal government has reduced the price of coal purchased by the province from the Cape Breton Development Corporation to fuel its power plants. Nova Scotia is now committed to reducing its annual SO_2 emissions to 204,000 tonnes before 31 December 1994, the date on which the agreement expires.

16 February 1988 - Environment Canada released a "National Sensitivity Assessment" map showing that 46% of Canada has a low ability to neutralize acidic precipitation. All regions of Canada have acid-sensitive areas but Quebec is the most sensitive, with 82% of its area having the lowest rating for neutralizing capacity. Newfoundland, Nova Scotia, and Ontario's Muskoka and Haliburton regions are also highly sensitive.

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17 March 1988 - Controversy continued over Canada's stand on NO_x emissions during negotiations within the Economic Commission for Europe (ECE) in Geneva. Critics alleged that the Canadian delegation has agreed with a U.S. proposal to raise the emission limits but Environment Canada officials have denied this. The Special Committee on Acid Rain has announced plans to study the issue through a series of public hearings.

29 March 1988 - Ontario Hydro gave an environmental assessment study to the provincial environment minister which estimated the capital cost of retrofitting its three major coal-fired generating plants with scrubbers at $3 billion. The three plants are Lambton near Sarnia, Lakeview in Etobicoke, and Nanticoke on Lake Erie southeast of Hamilton; they account for 93% of Ontario Hydro's coal-fired generation and are designed to burn medium-sulphur coals from the United States. If power demand is higher than anticipated during the 1990s, however, the capital cost could rise to $5.5 billion because as many as 20, rather than eight, scrubbers would be required to effect the necessary reduction in emissions.

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